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Supply Chain Modeling: Downstream Risk Assessment Methodology (DRAM)

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Agenda

- **Background**
- **Modeling Objectives**
- **Description of Approach**
  - **Modeling supply chains**
  - **Relating downstream shortfalls to risk**
- **Capability Demonstration Cases**
- **Observations**
- **Conclusions**

IDA Background

- Work sponsored by Defense Logistics Agency - Strategic Materials
- Build and implement for DLA SM and DoD an analytically rigorous risk-based process that can help DoD set priorities for risk mitigation (preparedness and investments) concerning strategic and critical non-fuel materials
  - Process began as raw material shortfall estimation to support National Defense Stockpile (NDS) planning
  - The Risk Assessment and Mitigation Framework for Strategic Materials (RAMF-SM) extended shortfall estimation and stockpile planning into risk assessment and mitigation (beyond stockpiling)
- Downstream Risk Assessment Methodology for strategic materials (DRAM) is now extending RAMF-SM into risk assessment and mitigation for *supply chains* downstream of raw material production

Objective for Today's Presentation

- Present DRAM capability and demonstrate its operation

Develop DRAM (Downstream Risk Assessment Methodology) — Objectives

- **Represent each important production step in global supply chain**
- **Estimate supply and demand at each step (node) in each supply chain on time-phased basis under conditions of National Defense Stockpile planning scenario (or others of interest)**
- **Model response of supply chain nodes to demand for goods, node capacity limits, and quantity of necessary feedstock material available to each node**
- **Model material shortfall risk mitigation measures applicable at each node of supply chain**
- **Reflect longer-term changes in technology, market, and security environment (alternative futures) in scenario conditions**
- **Quantitative approach is necessary to more precisely assess risk and evaluate and support proposed risk mitigation measures**

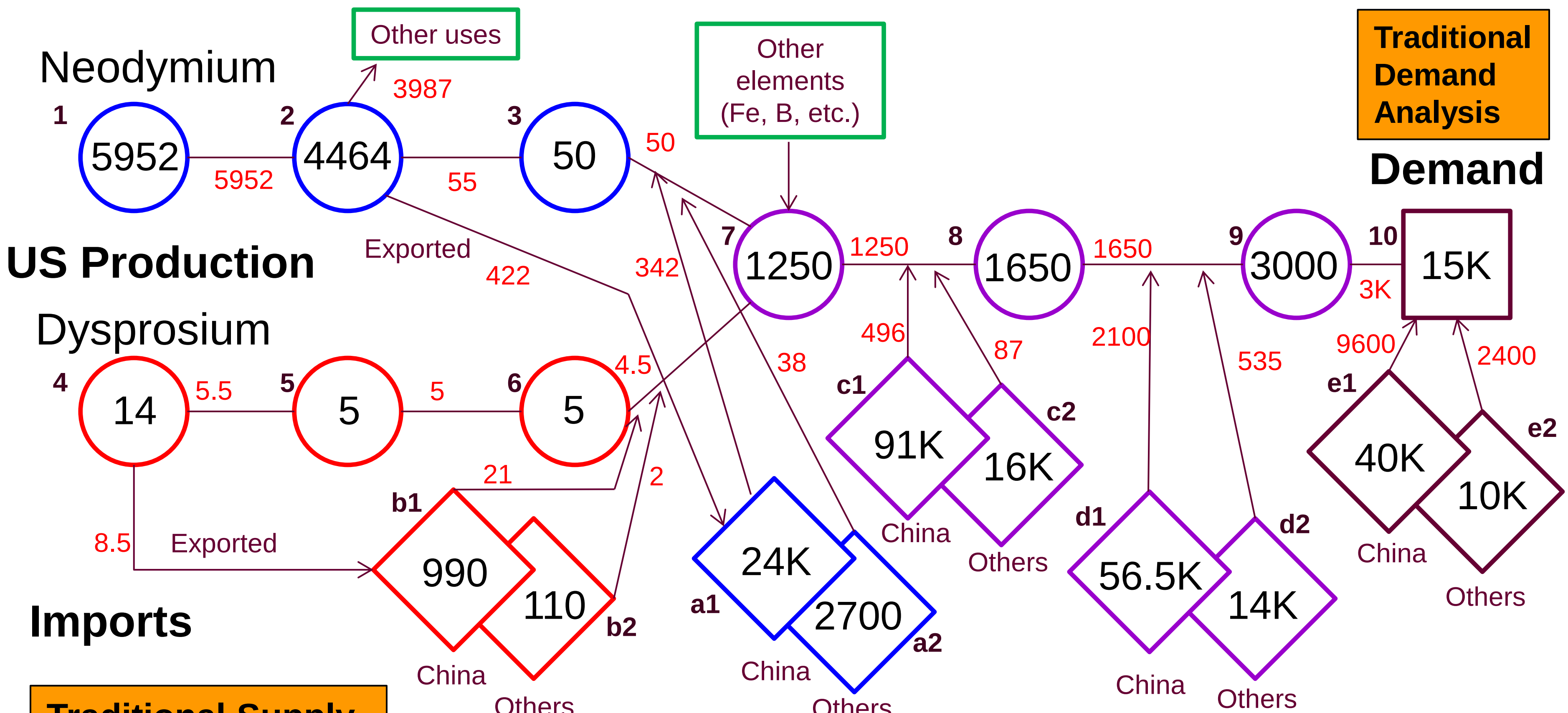
Develop DRAM—Approach

- Use neodymium iron boron magnet supply chain as basis for prototype
- Conduct literature review and canvass experts to identify desirable characteristics of supply chain model, approaches to modeling, and potential challenges
- Build model with characteristics to satisfy objectives
  - Material flows through nodes and shortfall estimation
  - Treatment of shortfall risk mitigation measures
- Demonstrate prototype DRAM using NdFeB magnets

Supply Chain Prototype: NdFeB Magnets
Legend: Node Capacity & Material Flows (MT/yr)

Stages of Production

Ore Mining	Separated Oxide Production	Metal Production	Alloy Production	Magnet Production	Magnet Fabrication



Traditional Supply Analysis

Supply Chain Analysis

Relating Downstream Material Shortfalls to Risk

- **Risk is defined as possibility of loss/harm:**
  - ***Risk = Probability of material shortfall* x *Consequences***
- **Probability of shortfall is, to first order, probability of scenario**
- **Consequences of shortfall in DRAM are consequences of shortage of final product**
  - **Consequences of "mid-stream" shortages are reflected in shortages of final products**
  - **Potential approaches to assessing consequences of final product shortfalls include:**
    - **Expert judgment**
    - **Elasticity of demand**
    - **Long-term price**
    - **Cost of production**

Cases Demonstrated

- *Peacetime supply and demand*
- Cutoff of imports from China
- Cutoff of imports from China with increased demand
- No imports (closed economy)
- *No imports and failure of U.S. sole source*

Demonstrations include product output, material flows, and shortfalls (if any)

Mitigation measures are demonstrated, with costs estimated, where shortfalls are found

Mitigation measure choices can be optimized for cost-effectiveness

DRAM quantitative approach enables more precise risk assessment and evaluation and support of proposed risk mitigation measures

Cases Presented in Today's Briefing

Material Shortfall Mitigation Measures

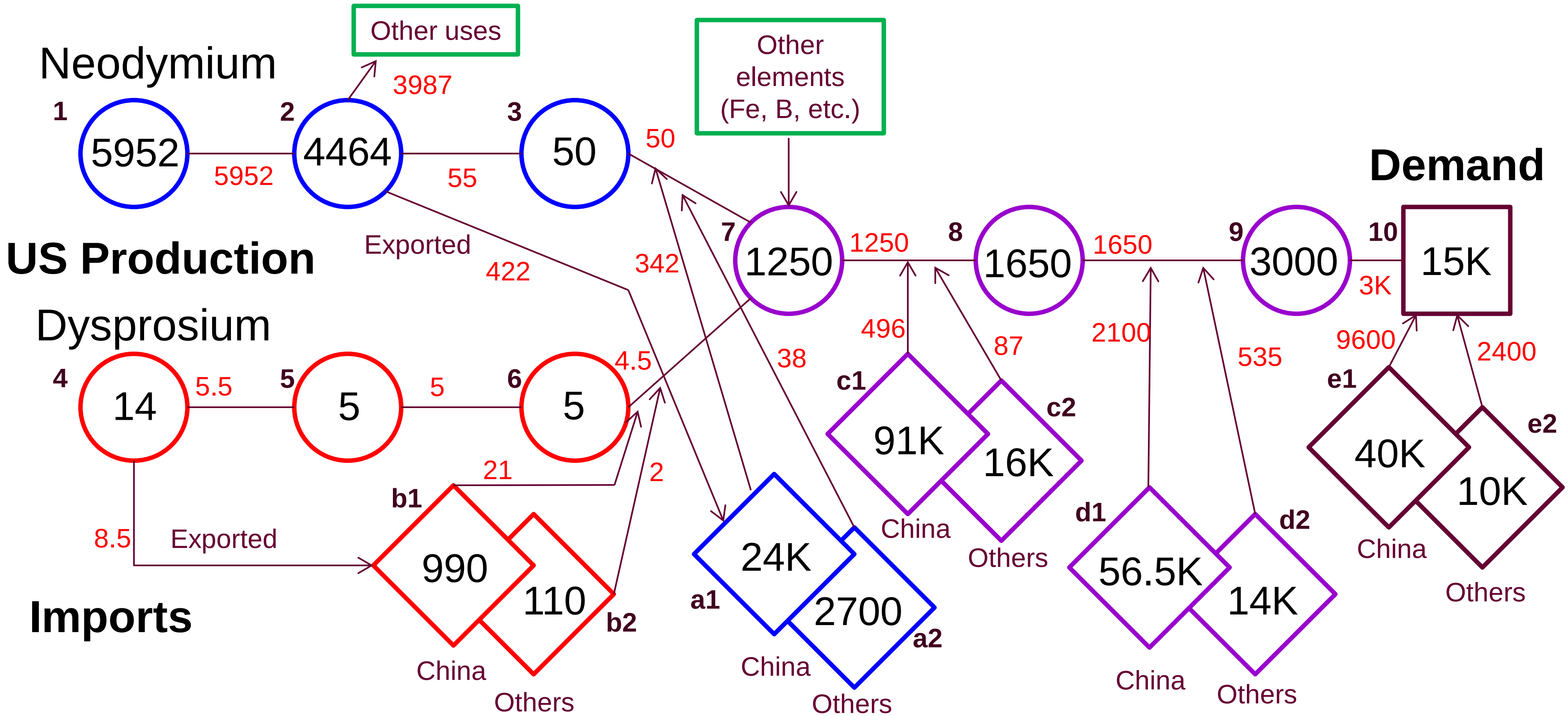
- ***Traditional government stockpiling***
- ***Other federal (or private) inventory options***
- ***Spot market purchases***
- **Futures contracts**
- **Reductions in government supply guarantees for exports**
- ***Substitution***
- ***Concerted material production programs (e.g., Title III)***
- **Enhanced recycling**
- **Security of foreign supply arrangements**

Included in Today's Briefing

Peacetime Supply and Demand Case
Legend: Node Capacity & Material Flows (MT/yr)

Stages of Production

Ore Mining	Separated Oxide Production	Metal Production	Alloy Production	Magnet Production	Magnet Fabrication



Peacetime Supply and Demand Observations

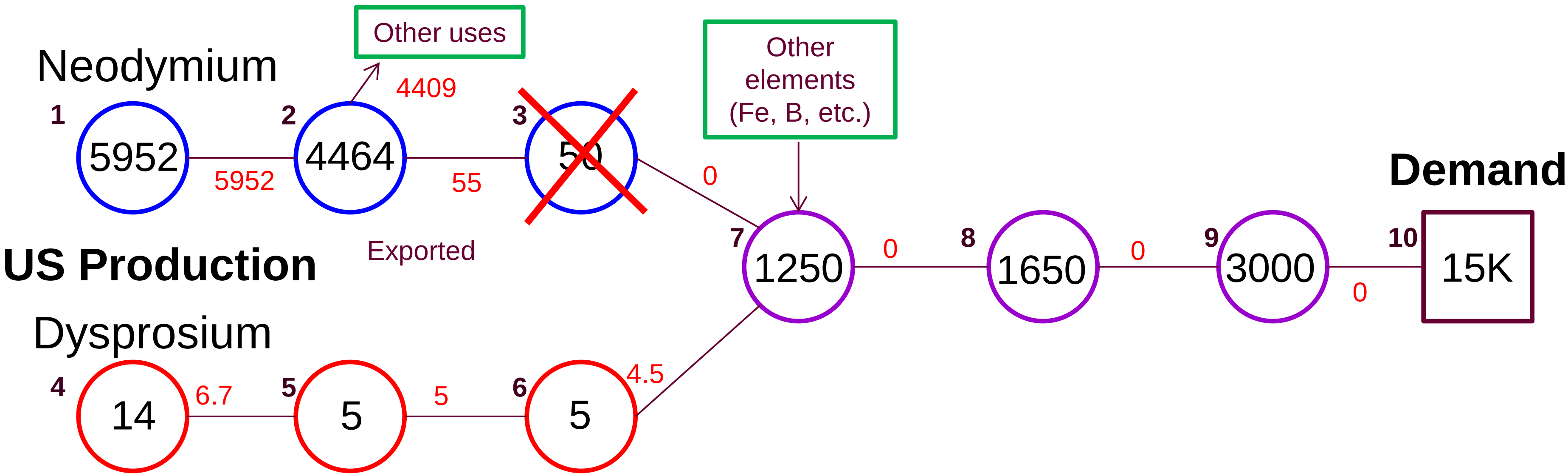
- Peacetime case shows material/product flows and production under normal conditions
- Demand met by combination of U.S. production and imports
- Material flows driven by demand for finished goods and requirements for producing upstream products, including process losses
- Imports feed U.S. supply chain at several points
- Imports sufficient to meet U.S. demand so long as U.S. market share is at least 24 percent

No Imports with Sole Source Cutoff Case

Legend: Node Capacity & Material Flows (MT/yr)

Stages of Production

Ore Mining	Separated Oxide Production	Metal Production	Alloy Production	Magnet Production	Magnet Fabrication



No Imports

No Imports with Sole Source Cutoff Case Observations

- Imports not available at all and sole source node cut off
  - Severe scenario for demonstrating modeling capability
- U.S. supply chain output constrained by lack of upstream capacity at several nodes
- One node—Nd metal production—is cut off entirely
  - Loss of critical node cuts off all US production of final product
  - All but Nd ore and oxide production insufficient to meet final demand
- Resulting shortfall = 15,000 MT magnets
- Mitigation measure(s) required at one or more nodes
  - Stockpiling
  - Other Inventory options (e.g., Buffer stock)
  - Spot market purchases
  - Substitution
  - Concerted Program (magnet production and fabrication)

No Imports with Sole Source Cutoff Case Analytical Assumptions

Assumptions generally consistent with those used in last National Defense Stockpile Requirements Report

- **One year shortfall in 4-year scenario**
- **Planning horizon = 5 years**
- **U.S. market share = 0% (no imports)**
- **Wartime price multiple = 15**
- **Probability of war = 0.0037**
- **Buffer stock rental cost = 15%/yr**
- **Cost = budget outlays (no recoupment)**

No Imports with Sole Source Cutoff Case Shortfall Risk Mitigation Options

Risk mitigation options: indicated below – including inventory sufficient to enable full use of existing U.S. production capacities

Inventory amounts:

- **Nd metal: 430 MT**
- **Dy oxide: 0.5 MT**
- **Dy metal: 22.5 MT**
- **Magnet alloy: 583 MT**
- **Magnet block: 2,635 MT**
- **Fabricated magnets: 12,000 MT**

Mitigation Measure	Amount Provided (MT)	Expected Cost (Budget) ($M)
Stockpiling	Amounts above	3,848
Inventory	Amounts above	2,900
Spot Market	0 (no imports)	0
Substitution	1,500 (magnets)	0
Conc. Program (magnet production)	0**	0

**No extra feedstock available

No Imports with Sole Source Cutoff Optimal Risk Mitigation Solution

- Shortfall mitigation options optimized for cost effectiveness
- Optimal measures under assumptions stated above
- Mitigation measure priority same as 2013 NDS Requirements Report

Mitigation Measure	Amount Provided (MT)	Expected Cost (Budget) ($M)
Substitution	1,500	0
Inventory (magnets)	10,500	2,074
Inventory (block)	2,635	459
Inventory (alloy)	583	35
Inventory (Dy metal)	22.5	13
Inventory (Dy oxide)	0.5	0.3
Inventory (Nd metal)	430	23
Total	**15,000 (magnets)**	**2,604**

IDA Modeling Observations

- Loss of sources within supply chain can create shortfalls depending on redundancy of network and U.S. market share of imports
  - Loss of single node could prevent production of final product
- Different mitigation measures may not be suitable for some nodes and scenarios (e.g., substitution, spot market)
- Capacities of nodes in domestic supply chains may not be balanced for self-sufficiency
  - Shortfall mitigation at multiple nodes may be required to allow production of final product at full domestic capacity
  - Options for shortfall mitigation may exist at multiple mid-stream nodes as well as final downstream node
  - Relative costs of shortfall mitigation at different nodes (e.g., mid-stream, downstream) may vary depending on material and nature of production process

IDA Conclusions

- Modeling capabilities demonstrated
  - Supply chains with material flows for multiple materials and multiple material suppliers
  - Multiple scenario conditions
    - Peacetime material flows
    - Increased demand
    - Cutoffs of material supplies from specified sources or all sources, including domestic
  - Shortfall risk mitigation measures evaluated
    - Applicable node by node and material by material
    - Effects on individual material flows, production of goods, and mitigation costs calculable
    - Can be optimized using specified priorities or to minimize cost or risk
- DRAM will be used to assess risk and evaluate mitigation measures for supply chains for FY 2015 NDS Requirements Report

BACK-UP

RAMF-SM Process and Steps

1 Identify Study Materials

Gather relevant data and set planning case assumptions

2 Estimate Shortfalls

3 Assess Shortfall Risks

4/5 Identify Mitigation Options

6 Prioritize Mitigation Options

Recommend Inventory Acquisitions

Supply chain modeling task adds downstream material considerations to the steps of RAMF-SM

New optimization model (OPTIM-SM) used to draw together all key factors and help guide prioritized investments